First observations of 4f$_{ce}$ auroral roar

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In the MF and HF bands up to 4.5 MHz, several types of electromagnetic emissions have been detected by recent satellite and ground-based observations: terrestrial hectometric radiation (THR), auroral roar and MF burst. Auroral roar is narrowband auroral radio emissions observable at ground level in the MF/HF range. Weatherwax et al. [1993] confirmed the occurrence of auroral roar near 2.5-2.8 MHz and discovered another component at 3.7-4.3 MHz. Because these frequencies are considered to be close to the second and third harmonics of the electron cyclotron frequency in emission sources, each type of auroral roar is called 2f$_{ce}$ roar and 3f$_{ce}$ roar. It has been believed that the auroral roar is originated from strong excitation of upper hybrid wave in the auroral ionosphere when f$_{UH}$~nf$_{ce}$ (n=2, 3) is satisfied and propagates to the ground after the mode conversion into the L-O mode electromagnetic wave. In this study, using spectrum measurement data obtained by ARS-S at Svalbard (75.2 CGM latitude), we present the existence of an additional frequency component of auroral roar, whose emission frequency range is 5.4-5.7 MHz. This type of auroral roar is referred to as 4f$_{ce}$ roar in this study, since this frequency range is equal to 4f$_{ce}$ in an altitude range of 170-310 km. Its long duration (from several minutes to several hours) and narrowband feature are similar to 2f$_{ce}$ and 3f$_{ce}$ roar; however, MLT dependence of 4f$_{ce}$ roar is different from that of 2f$_{ce}$ and 3f$_{ce}$ roar. 4f$_{ce}$ roar appears during 14-22 MLT (usually 17-19 MLT) and accompanies neither 2f$_{ce}$ nor 3f$_{ce}$ roar. 4f$_{ce}$ roar emissions started to appear after May 15, 2011, although upper limit of observation frequency of ARS-S was modified from 5 MHz to 6 MHz in October 2010. There are two possible candidates for the generation mechanism of 4f$_{ce}$ roar: (1) linear conversion of upper hybrid waves excited when f$_{UH}$~4f$_{ce}$ is satisfied and (2) nonlinear wave coupling between the two upper hybrid waves excited under the matching condition of f$_{UH}$~2f$_{ce}$. The former is a straightforward presumption based on the existing mechanism for generation of auroral roar, while the latter is originally proposed for the explanation of second harmonic THR emissions emanating from the topside ionosphere. Both the possible generation mechanisms require additional processes to explain the unexpected occurrence characteristics of 4f$_{ce}$ auroral roar.